Rocky Mountains Southwest Great Plains

Research Note RM-455

May 1985

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

Characteristics of Snags and Trees Containing Cavities in a Colorado Conifer Forest

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In Colorado a 160-ha forest of mature ponderosa pine—Douglas-fir contained 6.5 snags and spike-top trees per hectare. Of these, 0.9 per hectare had one or more cavities. In addition, there were 0.4 live cavity-trees per hectare. Most snags and spike-tops that contained cavities were in the larger diameter classes. The proportion of snags with cavities was equal among ponderosa pine, Douglas-fir, limber pine, and quaking aspen.

Keywords: Snags, cavities, wildlife, *Pinus ponderosa, Pseudotsuga menziesii, Populus tremuloides.*

Management Implications

As a group, birds that selected snags and live trees in which to excavate nesting cavities showed no preferences to any of the tree species present. Therefore, management of snags and cavities for wildlife can utilize the existing tree species composition, which varied topographically. Quaking aspen (*Populus tremuloides*) is the management focal species in bottoms and moist areas. However, because aspen snags remain standing for shorter periods than other species, more trees per area may be needed to ensure future snags. On lower- and mid-slopes, Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*), and on higher ridges limber pine (*Pinus flexilis*) and ponderosa pine, are the focal species. Snags and spike-top trees with diameters 24 cm and larger, because these had the highest frequency of cavities, provide the best potential habitat for cavity-excavating wildlife. Because populations of secondary cavity-nesters may be limited by the availability of cavities, retaining existing cavity-trees is important to these species.

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Introduction

Snags and exposed dead wood in live trees are required for roosting, nesting, and feeding by 85 species of North American birds (Scott et al. 1977). Most of these species either excavate cavities, use natural cavities, or use cavities created by other species. However, the number of snags is declining in managed forests, because they are cut for fuel and wood fiber, and because they are fire and safety hazards. In addition, as more forest lands are intensively managed for timber production, fewer stands are allowed to age beyond a prescribed rotation period. Thus, older forests, with large trees and large snags, are decreasing.

Although a model (Rasmussen and Ffolliott 1983) has been developed to estimate tree mortality and snag retention in some habitats, the dynamics of snag turnover (recruitment, decay, and eventual collapse of snags) make it difficult to accurately plan for snags over time. More information is needed on species composition, distribution, size and decay class frequencies, and occurrence of cavities in each of these categories under natural conditions. This study provides this data for an area of mature ponderosa pine and Douglas-fir forest in central Colorado.

Study Area

The study was conducted on a 160-ha area, in the eastern portion of Hotel Creek Watershed, on the Mani-

tou Experimental Forest, Colorado. The area was bounded on the north and south by east-to-west ridges that formed the watershed. The east and west boundaries were along north-south compass lines connecting the ridgetops. Elevations ranged from 2,580 m to 2,850 m.

The vegetation typified ponderosa pine forests in the central Rocky Mountains. Ponderosa pine, Douglas-fir, limber pine, blue spruce (*Picea pungens*), and quaking aspen were the overstory species. The major shrub species were cliffbush (*Jamesia americana*), common juniper (*Juniperus communis*), kinnikinnik (*Arctostaphylos uva-ursi*), squaw currant (*Ribes cereum*), shrubby cinquefoil (*Potentilla fruticosa*), woods rose (*Rosa woodsii*), and yucca (*Yucca glauca*). Most of the grasses were of the bunch type: bluegrass (*Poa* spp.), mountain muhly (*Muhlenbergia montana*), and bromes (*Bromes* spp.). Forest stands on the southern aspects, as well as on ridgetops, were generally open, mature stands of ponderosa pine, Douglas-fir, and limber pine; the northern aspects had younger, denser stands of Douglas-fir, aspen, and blue spruce.

Portions of the study area had been high-graded for railroad ties and mine timbers in the 1880s.[4] Fire-scarred snags in the south-central portion of the study area indicated that a small fire (5–20 ha) had occurred there. The fact that many large trees without fire scars existed in the burned area suggested that the fire either occurred before the 1880s or that it was a more recent ground fire which burned a few trees or existing snags.

Methods

The data were gathered from the center of a 4 km^2 area within which the breeding ecology and habitat affinities of flammulated owls (*Otus flammeolus*) were examined (Reynolds and Linkhart 1984). The 160-ha area was divided into 5 segments of 300 m width but of unequal lengths because of non-parallel ridge boundaries. Snags and cavities were located by traversing through one segment at a time. A "snag" was defined as any standing dead tree (no live foliage), and a "spike-top" as any tree whose crown (top portion) was more than 50% dead. A "live cavity-tree" was any live tree (not including spike-tops) which contained one or more cavities.

All snags and spike-tops greater than 20 cm diameter at breast height (d.b.h.) and 2.6 m high (smaller snags were included if they contained cavities) and not leaning greater than 45° from the vertical were marked with numbered metal tags. Diameter was measured with a diameter tape and height with an Abney level. The condition of each snag and spike-top tree was estimated as to the following: newly dead (retained all or nearly all terminal twigs); case-card or rotten (distinguished by chopping with a hatchet into the bole at breast height); amount of remaining bark (estimated as percentage of total height); and probable cause of death (lightning, insect, mistletoe, fire, unknown). Each snag and all live trees were searched for cavities with binoculars or 20X telescope. When possible, trees were climbed to distinguish cavities from incomplete excavations. All live cavity-trees were tagged and were measured and characterized the same way. Because the varied topography of the study area made it difficult to determine the area in each of three slope positions, the density of snags, spike-tops, and live cavity-trees was estimated along three parallel transects—one each in the creek bottom, mid-slope, and upper-slope—on the southern aspect of the major ridge. At 100-m intervals along each transect, points were located randomly (Reynolds et al. 1982) and were sampled with the point-centered quarter technique (Cottom and Curtis 1956). Distances from point to snag or cavity-tree, corrected for slope angle, were used to estimate density. Fifteen points were sampled along each transect; however, graphs of the running means (about points) (Kershaw 1964) stabilized after 10 points on each transect. The date of cavity-excavation and the condition of snags and live cavity-trees at the time of excavation were unknown.

Results and Discussion

A total of 985 snags, 47 spike-tops, and 58 live trees (with cavities) were counted (table 1). Of the snags and spike-tops, 126 (12.8%) and 16 (34.0%), respectively, contained cavities (total = 0.9/ha). Densities of snags, spike-tops, and live cavity-trees on the 160-ha study area were 6.2, 0.3, and 0.4 per hectare, respectively (total = 6.8/ha). For snags and trees containing cavities (of which only a few were natural, unexcavated cavities), the mean number of cavities per tree was 2.7 (SD = 2.58, range = 1–18), more than the 2.2 cavities per tree found in Oregon Douglas-fir forests (Mannan et al. 1980). The 6.5 snags and spike-tops per hectare in this study was higher than the 0.2–5.2 per hectare found in six small areas of ponderosa pine (each ≤15 ha) in Arizona (Cunningham et al. 1980). However, the densities reported by Cunningham et al. (1980) may be lower because they used larger diameter (30.5 cm) and height (6.1 m) limits. In another area in Arizona, Scott (1978),[5] found 13.1 snags per hectare in a 50-ha stand of ponderosa pine, Douglas-fir, and limber pine. Not only were there twice the number of snags per hectare in Scott's (1978) study, but there were also seven times the number of snags with cavities (6.4/ha in Arizona versus 0.9/ha in Colorado).

Percentages of 1090 snags and spike-tops (excluding live cavity-trees) in 10-cm d.b.h. classes (fig. 1) show that the diameter distribution was slightly right-skewed, with the mode occurring at class 2 (24.0–33.5 cm). Snags in the largest diameter classes (classes 4–6) are rarer because trees seldom live long enough to reach this girth (Lexen 1939, Cooper 1960). Tree height distribution in 3-m height classes was generally uniform through class 4 (11.2–14.1 m). Tree height was a decreasing function in the taller height classes (classes 5–7), because fewer

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Table 1.—Diameter (centimeters) and height (meters) of snags, spike-tops, and live cavity-trees on a 160-ha study area, Manitou Experimental Forest, Colorado.

	Snags		Spike-tops		Live	
	Diameter	Height	Diameter	Height	Diameter	Height
	N = 985		N = 47		N = 58	
Mean	31.45	7.80	34.75	11.70	31.24	12.56
SD	9.81	4.33	9.56	3.94	10.65	4.04
Maximum	74.0	23.5	61.0	18.6	61.5	19.8
Minimum	14.0	2.1	20.5	2.7	18.0	2.7

trees grow to these heights, and because older snags are more likely to lose their tops as a result of deterioration from insects, fungi and bacteria, weather (Kimmey 1955), and weakening caused by the presence of nest cavities. In the study area, the last occurred most often in aspen, because their diameters tended to be smaller (table 2) and cavities occupied a greater proportion of trees' supporting tissues.

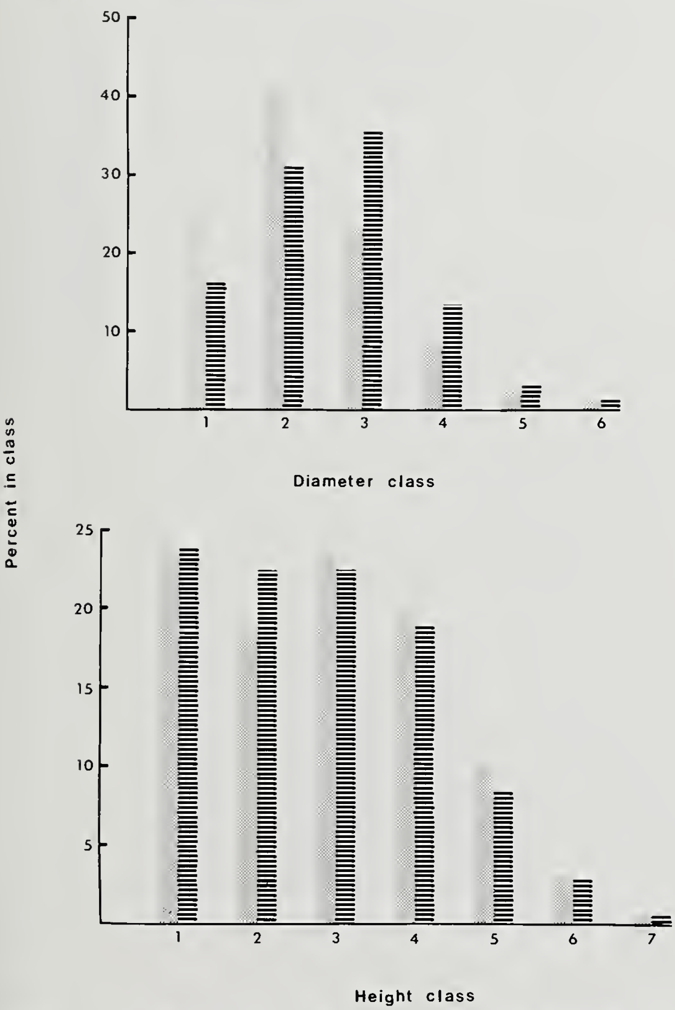

Figure 1.—Percentage of snags and spike-tops in diameter and height classes (stippled bars) and the percent of trees containing at least one cavity in each class (striped bars). Diameter (centimeters) classes: 1, 14.0-23.5; 2, 24.0-33.5; 3, 34.0-43.5; 4, 44.0-53.5; 5, 54.0-63.5; 6, 64.0-74.0. Height (meters) classes: 1, 2.1-5.0; 2, 5.1-8.0; 3, 8.1-11.1; 4, 11.2-14.1; 5, 14.2-17.2; 6, 17.3-20.2; 7, 20.3-23.5.

Distribution of snags and live cavity-trees was not uniform across slope positions in the study area. In the point-centered quarter sample, there were nearly four times more snags, spike-tops, and live cavity-trees on the upper-slope as on the mid-slope and bottom areas (12.4/ha versus 3.4 and 3.3/ha, respectively). These differences appeared to be related to varying stand densities and mortality factors among slope positions. At least on the southern aspect of the major ridge, stands in the bottom and along the mid-slope generally were more open than on the upper-slope—there were fewer trees, and, therefore, fewer snag candidates on the lower slope positions. In addition, damage and mortality from lightning and wind were more common on upper slopes and ridgetops than at lower elevations. Other possibilities include longevity differences among snag species (e.g., limber pine snags, which occurred on the upper slopes, appeared to be much older than aspen snags, which occurred along bottoms), and greater access for firewood cutters along the bottom. The proportion of snags and spike-tops with cavities in each of the three slope positions was nearly equal (upper-slope = 19%; mid-slope = 19%; bottom = 17%); thus, there were nearly four times as many cavities along the upper-slope as elsewhere.

The number of snags and spike-tops (excluding live cavity-trees) was not equally distributed among the five tree species ($\chi^2_{(4)} = 862.7$, $P < 0.05$) (tables 2 and 3). However, despite the large differences in frequencies among species, there was an equivalent proportion of snags and spike-tops with cavities among species ($\chi^2_{(4)} = 3.89$, $P > 0.05$) (table 3). This was also the case within each slope position. Although the number of trees in the sample was small, a rank ordering of the four most common species of snags and spike-tops from the most to least common was matched in all but one case by a similar ordering of the most to least common species with cavities. Thus, the cavity-excavating species that nested in the study area, at least in aggregate, appeared to excavate cavities in species of snags in proportion to the abundance of each species. However, there was a significant difference ($\chi^2_{(5)} = 21.2$, $P < 0.05$) in the frequency of snags and spike-top trees with cavities among diameter classes—83.8% of trees containing cavities had diameters greater than 24 cm (fig. 1). No preferences were detected among height classes ($\chi^2_{(6)} = 1.79$ $P > 0.05$). With the exception of blue spruce, which contained no cavities, there was a near equal frequency of tree species among live cavity-trees (table 4).

Table 2.—Number, diameter at breast height (centimeters), and height (meters) of all snags and spike-tops (N = 1,032) by species on a 160-ha area, Manitou Experimental Forest, Colorado.

Species	N	Diameter (SD)	Height (SD)
Douglas-fir	515(49.9)[1]	32.70(10.63)	7.60(3.93)
ponderosa pine	337(32.7)	32.47(9.14)	10.62(4.30)
quaking aspen	79(7.7)	23.63(4.93)	11.55(4.35)
limber pine	72(7.0)	30.14(7.77)	9.90(2.94)
blue spruce	29(2.8)	27.43(4.63)	10.78(5.09)

[1]*Numbers in parentheses represent percentage of 1,032 trees.*

Table 3.—Number, diameter (centimeters), height (meters), and percent with cavities[1] of snags and spike-tops containing cavities on a 160-ha area, Manitou Experimental Forest, Colorado.

Species	N	Percent with cavities	Diameter (SD)	Height (SD)
Douglas-fir	70	13.6	36.79(10.62)	7.40(4.03)
ponderosa pine	47	14.0	36.05(9.07)	10.67(4.63)
quaking aspen	15	19.0	22.43(5.93)	9.27(4.34)
limber pine	9	12.5	31.61(5.94)	9.28(2.24)
blue spruce	1	3.5	25.50	11.28

[1]*Numbers of snags and spike-tops with at least one cavity/total number of snags and spike-tops per species (see table 2).*

Table 4.—Number, diameter (centimeters), and height (meters) of live cavity-trees (N = 58) on a 160-ha area, Manitou Experimental Forest, Colorado.

Species	N	Diameter (SD)	Height (SD)
Douglas-fir	15(17.2)[1]	39.80(9.22)	10.85(3.50)
ponderosa pine	13(22.4)	44.39(9.56)	14.42(3.86)
quaking aspen	17(29.3)	26.68(5.15)	14.84(1.86)
limber pine	18(31.0)	37.42(9.74)	10.01(4.22)
blue spruce	--	--	--

[1]*Percentage of 58 trees.*

Height was significantly greater ($T = -5.57$, $P < 0.05$) for live cavity-trees than for snags and spike-tops with cavities combined. This difference may have resulted from the fact that live trees did not have as equal an opportunity as dead trees to lose their tops. There was no significant difference ($T = -0.99$, $P > 0.05$) in diameter between these two groups.

Excluding spike-tops, most snags (64.3%) were case-hardened, 10.2% were rotten, and 25.6% were newly dead (table 5). Most snags (60.2%) retained more than 50% of their bark; 25.4% of the snags retained less than 50%. Those without any bark constituted 14.4% of snags. Scott (1978) found that the percentage of bark retained was not a good estimator of snag age. Except for

Table 5.—Selected characteristics of 985 snags (excluding spike-tops) on a 160-ha area, Manitou Experimental Forest, Colorado.

Condition	N	Percent of total	Number of snags with cavities	Percent of group with cavities
Newly dead	252	25.6	5	2.0
Case-hard	633	64.3	106	16.7
Rotten	100	10.2	15	15.0
>50% bark	593	60.2	67	11.3
<50% bark	250	25.4	39	15.6
No bark	142	14.4	20	14.1

the newly dead snags, the percentage of snags with cavities was nearly equal among the six condition classes (table 5). The low frequency of cavities in new snags probably was related to the short period of availability and perhaps lack of suitable decay conditions. Scott (1978) found that ponderosa pine snags that retained small, terminal twigs had been dead an average of 3.2 years, and that snags usually did not become suitable for excavation until 6 years after death. Case-hardened snags, although the most numerous on the study area, had only a slightly higher percentage with cavities than snags classes as rotten. As expected, many cavities in rotten snags were old, and some of those may have been unsuitable for secondary cavity-nesters.

Among the indentifiable causes of death, insects—mostly mountain pine beetle (*Dendroctonus ponderosae*) and western spruce budworm (*Choristoneura occidentalis*)—accounted for the majority (9.8% of total snags), followed by fire (8.3%), and lightning (2.2%). However, it was not determined whether fire-scarred snags had been killed by fire (perhaps lightning-caused) or were burned after death. Six (12.8%) spike-tops and 10 (17.2%) live cavity-trees had evidence of lightning strikes, usually in the form of an exposed strip of heartwood along a portion of the bole.

Conclusions

Within the Colorado montane zone, Douglas-fir and ponderosa pine are important snag species on all slopes and aspects. Aspen is an important cavity-tree, especially in moist bottoms where it is frequently the dominant tree. However, the slender trunk structure of aspen and the high incidence of fungal rot in trunks and roots (Davidson, Hawksworth, and Hinds 1959), predisposes this species to windfall soon after death. In the study area, for example, aspen stands contained many downed but hard-cased logs, and none of the aspen snags in this study had stood sufficiently long to be classed as rotten. The rate of decay and high turnover requires that a greater number of aspen trees be retained to obtain future snags. The rate of cavity loss in aspen can be slowed somewhat by retaining all live aspen that have existing cavities. Limber pine, which occurs primarily along ridgetops, is an important cavity-tree because older trees frequently have one or more dead trunks which are particularly long-lived. Because dead wood of limber pine is dry, snags and cavities deteriorate at a slower rate than in other species. Retaining existing limber pine cavity-trees, especially if alive, should provide cavities well into the future.

Many cavity-using vertebrates have different ecological requirements that may be associated with, for example, forest type, foliage volume, or slope position. In addition, because many of these species are territorial, their populations tend to be overdispersed. Thus, management activities that result in clumped cavity-trees may reduce populations of cavity-users.

Finally, because little is known of the aging process of snags and how tree-age and extent of decay relate to preference by cavity-excavators, the best initial strategy may be to save those trees and/or snags that have existing cavities. Even if a snag or tree is beyond conditions that are suitable for further cavity-excavation, existing cavities may be used by secondary cavity-nesters. The importance of existing cavities was demonstrated by Balda (1975), who found that secondary cavity-nesters may contribute up to 55% of breeding individuals and 33% of all breeding species in ponderosa pine forests.

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GPO 846-815